PB-213 911

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The Uptake of Cerium-144, Promethium-147, and Plutonium-238 by Oat Plants from Soils

S. L. Cummings and L. Bankert[1]

The uptakes of cerium-144, promethium-147, and plutonium-238 by oat plants were determined for nine soils, and promethium-147 and plutonium-238 uptakes were compared with cerium-144 uptake. The percentage uptake values for all three radionuclides were very low, ranging from 10^{-6} to 10^{-3} percent. Nitrogen and potassium fertilizers increased the uptake of promethium-147 by oat plants from an Amite soil. Because the amount of cerium-144, promethium-147, and plutonium-238 taken up by plants from soils is very small, the health hazards to man by the soil-plant-man pathway from these radionuclides will probably be negligible at the levels used in this study.

With the uses and proposed uses of radionuclides as heat sources in auxiliary space batteries, it is important to know to what extent these radionuclides will be taken up from soils by plants in the event a land area becomes contaminated from an abortive flight. Two radionuclides of interest for which very limited information is available on plant uptake from soils are promethium-147 and plutonium-238 (*1,2*).

Since sample preparation for counting plutonium-238 (primarily an alpha emitter) and promethium-147 (primarily a beta emitter) involves much more time than for gamma-emitting radionuclides and since the maximum permissible body burden of plutonium-238 is quite low, it would be advantageous to be able to relate promethium-147 and plutonium-238 uptake by plants from soils to some radionuclide, e. g., cerium-144, that is easily prepared for counting and much less hazardous to handle when performing plant uptake experiments. Therefore, the objectives of this study were to determine to what extent promethium-147 and plutonium-238 are taken up from different soils and to see if this uptake could be related to cerium-144 uptake.

Materials and methods

Properties and collection locations of the soils used in this investigation are given in table 1. One-pint plastic cottage cheese containers (80 cm^2 surface area) were used to contain the soils for the plant uptake experiments. The containers were partially filled with soil leaving approximately 1 cm of space at the top. The activity (100 μCi of cerium-144 chloride, 100 μCi of promethium-147 chloride, and 50 μCi of plutonium-238 nitrate solution) was uniformly applied to the

Table 1. Soil properties

Soil series	Cation exchange capacity (meq/100 g)	Organic matter (percent)	pH
Fox (Ohio)	9.15	2.7	7.3
Blanton (Florida)	2.62	2.7	5.4
Lakeland (Florida)	1.75	2.2	5.5
Adamsville (Florida)	3.02	1.3	5.9
Ruskin (Florida)	4.63	3.0	5.6
Leon (Florida)	1.53	6.1	5.5
Congaree (Alabama)	3.49	2.5	5.5
Ochlockonee (Alabama)	8.80	1.8	5.9
Amite (Alabama)	2.67	1.6	6.3

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soil surface of the partially filled container and additional soil added so that the activity was 1 cm below the soil surface (*3*). Each soil was replicated three times for each radionuclide. One soil (Amite) was used to determine the effect of nitrogen, phosphorus, and potassium on the uptake of promethium-147. Nitrogen, phosphorus, and potassium salts, separately and in combination, were thoroughly mixed with the soil. Thirty oat seeds (*Avena sativa* var. Suregrain) were planted in each container. Oats were chosen as an indicator crop because of their rapid growth and thinned to 20 plants after emergence. The containers were randomly placed in a controlled environment chamber maintained at day and night temperatures of 25° and 18° C, respectively, and day and night relative humidities of 62 and 75 percent, respectively, with a 14-hour photoperiod. Soil moisture tension was adjusted to 0.1 bar by daily watering. Shoots of all plants were collected 3 weeks after planting. Cerium-144 was determined by gamma spectroscopy on dried samples (70° C). Promethium-147 and plutonium-238 levels were determined with an internal proportional counter after the plants had been dry ashed. The soil cation exchange capacity, organic matter content, and pH (1:1 soil-water ratio) were determined by previously published procedures (*3,4*).

Results and discussion

The percentage uptakes of cerium-144, promethium-147, and plutonium-238 by oat plants from all soils were very low (table 2). Some of these values were as much as six orders of magnitude lower than strontium-85 and cesium-137 oat plant percentage uptakes from the same soils (*3*). The uptake of cerium-144 was greater than promethium-147 from six of the nine soils and greater than plutonium-238 from all nine soils. These results are in general agreement with previous work (*1,2*).

The linear correlation coefficient of promethium-147 uptake with respect to cerium-144 uptake was 0.95 and plutonium-238 uptake with respect to cerium-144 uptake was 0.47. The relationship between cerium-144 and promethium-147 is quite good and much better than the cerium-144 and plutonium-238 relationship. Although these results are for a limited number of soils, they can be used as a guide to future plant uptake studies with these radionuclides. Additional work with more soils will help verify these results.

An Amite soil was used to determine the effect of nitrogen, phosphorus, and potassium fertilizer salts on oat plant uptake of promethium-147 because of the limited amount of this type of information available for this radionuclide (*5*). The results are given in table 3. Nitrogen and potassium fertilization increased promethium-147 uptake while phosphorus had no significant effect. Nitrogen had a greater enhancing effect than did potassium for this particular soil.

Because the soil-to-plant as well as the food-to-man (*6*) transfer of these three radionuclides is very small, the possible health hazards to man from this pathway would likely be negligible

Table 2. Percentage uptake of cerium-144, promethium-147, and plutonium-238 by oat plants

Soil series	Percentage uptake[a]		
	Cerium-144 ($\times 10^{-6}$)	Promethium-147 ($\times 10^{-6}$)	Plutonium-238 ($\times 10^{-6}$)
Fox (Ohio)	[b]0.53±0.07	0.58±0.06	0.07±0.01
Blanton (Florida)	13.1 ±1.4	7.8 ±2.1	.10± .04
Lakeland (Florida)	14.0 ±1.7	10.5 ± .72	.61± .10
Adamsville (Florida)	2.56± .85	.92± .08	1.20± .37
Ruskin (Florida)	2.70± .16	.96± .13	.53± .24
Leon (Florida)	5.00± .33	2.76± .25	.40± .20
Congaree (Alabama)	26.5 ±2.9	33.9 ±3.6	2.2 ±1.1
Ochlockonee (Alabama)	8.7 ±1.9	8.92± .21	.33± .10
Amite (Alabama)	7.93± .80	5.54± .08	2.28± .56

[a] Percentage uptake is the ratio of the activity in all the plants to the total activity applied to the soil times 100.
[b] Plus or minus 1 standard deviation.

Table 3. The effect of nitrogen, phosphorus, and potassium on the percentage uptake of promethium-147 by oat plants from an Amite soil

Application rate (kg/hectare)			Percentage uptake[a] ($\times 10^{-6}$)	Plant weight (mg dry weight)
N	P	K		
0	0	0	[b]5.54±0.08	605
[c]560	0	0	10.6 ±1.1	649
0	0	[d]560	6.66± .86	590
[c]560	0	[d]560	17.6 ±2.8	709
[c]560	[e]560	0	9.4 ±1.1	712
0	[e]560	[d,f]560	4.83± .20	641
[c]560	[e]560	[d,f]560	17.3 ±2.4	701

[a] Percentage uptake is the ratio of the activity in all the plants to the total activity applied to the soil times 100.
[b] Plus or minus 1 standard deviation.
[c] Ammonium nitrate.
[d] Potassium chloride.
[e] Sodium dihydrogen phosphate.
[f] Potassium dihydrogen phosphate.

at the levels used in this study. This statement may not apply to root crops, which preliminary studies indicate may retain certain isotopes in greater concentrations than the above ground portion.[2]

[2] Personal communication from the Southwestern Radiological Health Laboratory, January 14, 1971.

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3